National Aeronautics and Space Administration

2017 ECLIPSE ACROSS AMERICA THROUGH THE EYES OF NASA

Subject Matter Experts Training Materials

Version 1 • February 27, 2017

www.nasa.gov

Image Credit: S. Habbal, M. Druckmüller and P. Aniol

Join us in our efforts to engage the public about the August 21, 2017 total solar eclipse by volunteering as a Subject Matter Expert!

This is the first total solar eclipse visible in the contiguous U.S. in 38 years. The path of totality crosses 14 states. The states in the path of totality are: Oregon, Montana, Idaho, Wyoming, Nebraska, Iowa, Kansas, Missouri, Illinois, Kentucky, Tennessee, Georgia, North Carolina and South Carolina. Outside the path of totality, the rest of the continental U.S. will be within the Moon's penumbral shadow, where the Moon only partially blocks the sun and creates a partial solar eclipse. The partial eclipse begins in the continental U.S. near Lincoln City, Oregon, at 9:05 a.m. PDT, and totality begins in this location at 10:16 a.m. PDT. The total eclipse will end in Charleston, South Carolina, at 2:48 p.m. EDT, and the partial eclipse ends in the continental U.S. in this location at 4:09 p.m. EDT.

SUBJECT MATTER EXPERTS

A eclipse subject matter expert, or SME, in this context is a person with knowledge of why eclipses happen, this particular eclipse and NASA's interest and role. A SME should have a basic working knowledge of astronomy especially eclipses and the sun-Earth-Moon system.

We welcome scientists, engineers, science writers, amateur astronomers, and science educators to identify themselves as subject matter experts (SMEs) for the 2017 Total Solar Eclipse.

NASA INVOLVEMENT - 2017 TOTAL SOLAR ECLIPSE

"…The expansion of human knowledge of the Earth and of phenomena in the atmosphere and space…" and to "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof…"

– 1958 NASA Space Act, as amended

- NASA made a decision in September 2016 that the entire agency support the 2017 total solar eclipse.
- Science Mission Directorate (SMD) began intra-Center coordination activities in October 2016 to avoid duplication and ensure awareness of other activities. Five main NASA attributes:

1. Safety – NASA's #1 core value and the #1 priority during any event
2. Science – Awareness of missions, science and return on investment
3. Education – Fundamental learning opportunity of nature's processes
4. Public Engagement – Unique opportunity for all U.S. to participate
5. Citizen Science – Several apps for citizens to gather data on nature's processes

SAFETY FIRST

NASA's #1 core value is safety. During the event this includes:

- Eye Safety
- Eye Safety Devices
- When to Wear Eclipse Viewing Glasses
- Event Location Safety Plans and Tips

EYE SAFETY DURING AN ECLIPSE

It's NEVER safe to look directly at the sun, except when the sun is completely blocked during the period of a total eclipse known as *TOTALITY*.

WHERE TO WATCH

Find a nice, clear spot with a good view of the sky.

HOW TO WATCH

You can see the sun and the eclipse with special eclipse glasses. NEVER look directly at the sun without appropriate eyewear. More: *http://eclipse2017.nasa.gov/safety*

HOW LONG WILL IT LAST

The total eclipse, when the sun is completely blocked by the Moon, will last up to 2 minutes and 40 seconds, depending on your location.

SAFELY observing THE SUN

Credit: S. Habbal, M. Druckmüller and P. Aniol

WARNING! Never look directly at the sun without proper eye protection. You can ***seriously*** injure your eyes.

Check with local science museums, schools and astronomy clubs for eclipse glasses—or purchase an ISO 12312-2 compliant and CE certified pair of these special shades!

Inexpensive and easy to build, the sun funnel is a device that completely encloses the light coming from a telescope and projects a magnified image of the sun, large enough for many people to view at once.
http://eclipse2017.nasa.gov/make-sun-funnel

EYE SAFETY: WHEN TO WEAR THE GLASSES

PRACTICE WITH YOUR AUDIENCES!!

1 PARTIAL ECLIPSE • GLASSES ON
The eclipse begins when the sun's disk is partially blocked by the Moon. This partial eclipse phase can last over an hour.

2 BAILY'S BEADS • GLASSES ON
As totality approaches, only the low-lying valleys on the Moon's edge allow sunlight through, forming bright spots of light called Baily's Beads.

3 DIAMOND RING • GLASSES ON
The last of the sunlight streaming through the Moon's valleys creates a single bright flash of light on the side of the Moon. This is known as the diamond ring effect, and it marks the last few seconds before totality begins.

4 TOTALITY • GLASSES OFF
Once the diamond ring disappears and the Moon completely covers the entire disk of the sun, you may safely look at the eclipse without a solar filter. Be careful to protect your eyes again before the end of totality—the total eclipse may last less than a minute in some locations.

5 FINAL STAGES • GLASSES ON
A crescent will begin to grow on the opposite side of the sun from where the Baily's Beads shone at the beginning. This crescent is the lower atmosphere of the sun, beginning to peek out from behind the Moon and it is your signal to stop looking directly at the eclipse. Make sure you have safety glasses back on—or are otherwise watching the eclipse through a safe, indirect method—before the first flash of sunlight appears around the edges of the Moon.

Images 1 and 3-5 Credit: Rick Fienberg, TravelQuest International and Wilderness Travel
Image 2 Credit: Arne Danielson

SAFETY PLANS

- Familiarize yourself with the event's safety plan. The event coordinate should be able to provide you with the details:
  1. Event Safety and Security Planning
  2. Crowd Management
  3. Transportation Management
  4. Emergency Plan
  5. First-Aid Plan

- See sample safety plans provided in the following:
  - *http://www.waitakere.govt.nz/Frefor/pdf/event-safety-guidelines-osh-200104.pdf*
  - *https://www.seattle.gov/Documents/Departments/SpecialEvents/SeattleSpecialEventPublicSafetyPlan.pdf*
  - *http://www.emich.edu/bookemu/documents/checklist.pdf*
  - *https://www.westsomersetonline.gov.uk/getattachment/Environment/Licensing/Event-Safety-Guide-for-Organisers-pdf.pdf*

- Find additional safety tips at:
  - *https://eclipse2017.nasa.gov/sites/default/files/publications/Safety_508.pdf*

II. SCIENCE

Awareness of missions, science and return on investment:

- NASA science missions and programs
- Seeing the sun
- Observing from the ground
- Observing Earth
- Studying the Moon
- Tracking planetary eclipses
- Finding exoplanets

ECLIPSE 2017: NASA SCIENCE

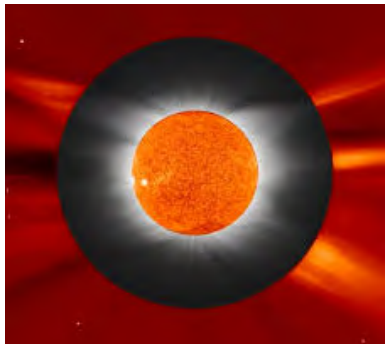
- NASA tests new instruments and leverages the skills of citizen scientists to expand our understanding of the sun-Earth-Moon system.
- To study the sun's corona, scientists create special spacecraft instruments called coronagraphs to block the sun's visible light, but total eclipses provide the best possible observations of the corona in visible light.
- Total solar eclipses also provide an opportunity to study Earth under uncommon conditions. The sudden blocking of the sun during an eclipse reduces the light and temperature on the ground, and these quick-changing conditions can affect weather, vegetation and animal behavior.
- In addition to conducting eclipse observations with spacecraft, NASA funds experiments on the ground and from planes to study the sun and Earth, including land and atmospheric responses.
- NASA's Solar Probe Plus, which will launch in 2018, will fly right into the sun's atmosphere to provide our first-ever direct observations of the corona.
- An eclipse is a specialized transit—any time one celestial object passes in front of another. Transits are key for discovering exoplanets: missions such as NASA's TESS and Kepler have instruments for determining when a planet passes in front of a star even if the planet itself is far too small for us to see from Earth.

SEEING THE SOLAR CORONA AND OBSERVING THE SOLAR ECLIPSE

Several NASA missions will be capturing observations of the sun or Earth during the 2017 eclipse. Most of the imagery will not be available in real time, but will be shared publicly within the next few days.

- NASA missions to observe the Moon pass in front of the sun:
  - Hinode (joint mission with JAXA) and the Interface Region Imaging Spectrograph.
- NASA missions to observe the solar corona (but no image of eclipse):
  - Solar Dynamics Observatory, the Solar and Heliospheric Observatory and the Solar Terrestrial Relations Observatory.
- NASA missions to observe Earth during eclipse:
  - Lunar Reconnaissance Orbiter, the International Space Station and NOAA's Deep Space Climate Observatory.

https://eclipse2017.nasa.gov/observations



A composite of the corona during a total solar eclipse in Greece superimposed on a Solar and Heliospheric Observatory (SOHO) image. Credit: The Williams College Eclipse Expedition with support from NSF/NASA/ National Geographic.

Hinode observed the solar eclipse of May 20, 2012.
Credit: Hinode/XRT

OBSERVING THE ECLIPSE FROM THE GROUND

- NASA scientists Drs. Nat Gopalswamy and Nelson Reginald will see the inner corona with their improved instruments during the solar eclipse.

- NASA scientist Guoyong Wen will compare observations from two satellites and three ground-based atmospheric instruments to calculate how the eclipse affects the flow of energy into, out of, and throughout Earth's atmosphere.

Credit: National Solar Observatory/Matt Penn

- NASA funded a team to train volunteers to collect images of the eclipse for the Citizen Continental-America Telescopic Eclipse (CATE) Experiment to study the dynamics of the inner solar corona.

OBSERVING THE ECLIPSE FROM THE GROUND: GLOBE

- GLOBE is a citizen science project that uses an app to observe how the eclipse changes atmospheric conditions:
  - Cloud types and cover
  - Air temperature – with a simple thermometer
  - Surface temperature – with an infrared thermometer and online training

Learn more at *observer.globe.gov*



Credits: NASA/GLOBE

OBSERVING THE ECLIPSE FROM THE GROUND (CONT.)

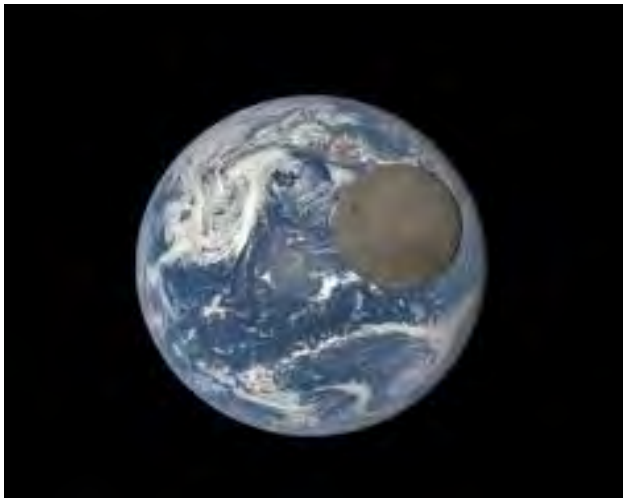
Total solar eclipses help us understand the sun-Earth connection. NASA is funding sun-focused and Earth-focused studies:

- Physics of the coronal plasma
- Measuring temperature and flow speed in the solar corona
- Interdisciplinary airborne science from NASA's WB-57
- Measuring the infrared solar corona
- Citizen science: measuring the polarization of solar corona
- Rosetta-stone experiments at infrared and visible wavelengths
- Induced changes in the ionosphere over the continental U.S.
- Contributions of ionization sources on the ionosphere
- Empirically-guided solar eclipse modeling
- Using spacecraft and ground-based instruments for radiative transfer
- Land and atmospheric responses

Credit: NASA

See more at:
http://go.nasa.gov/2kAbPzu

OBSERVING EARTH DURING THE ECLIPSE



Credit: NASA/NOAA

Credit: NASA/ISS

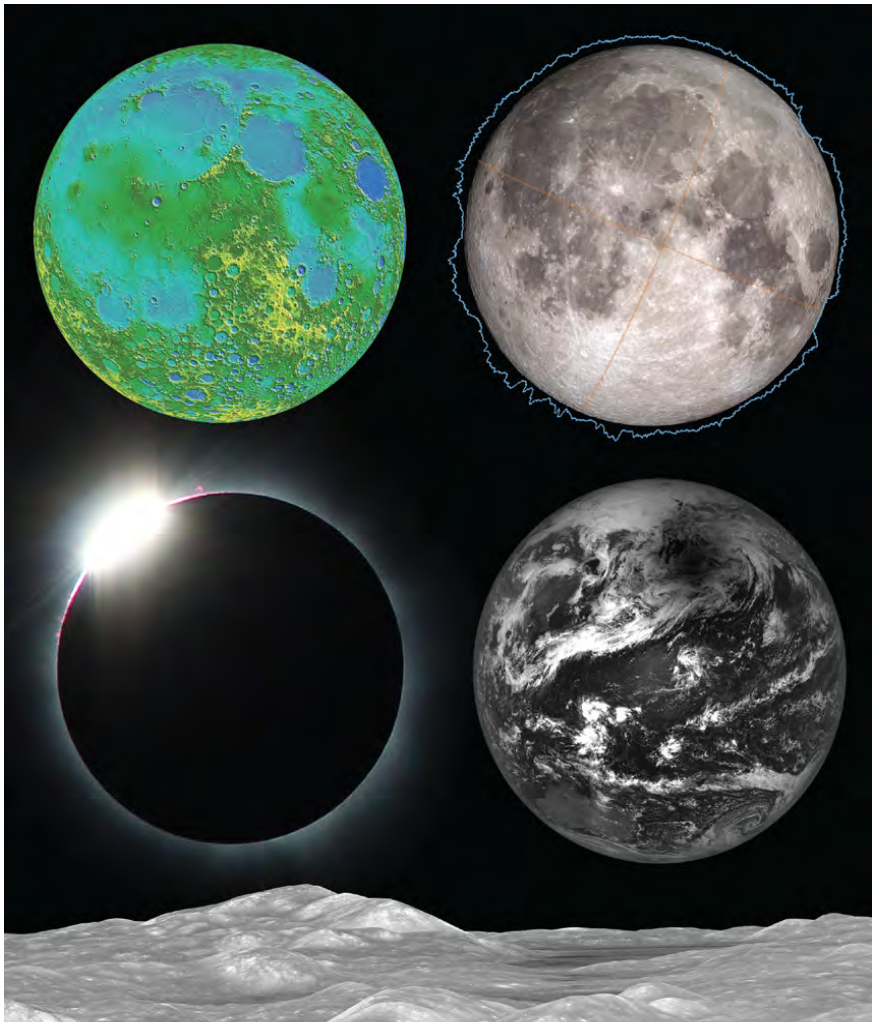
- NOAA's Deep Space Climate Observatory (DSCOVR) will collect images every 15 minutes and provide them within the next 1-2 days at *http://epic.gsfc.nasa.gov*
- **By late June 2017, the International Space Station will know if it is in a position to observe the Moon's umbral, or inner, shadow during the eclipse on August 21, 2017.**
- TERRA, AQUA, SNPP, LANDSAT 7 & 8 may also see the Moon's shadow if they pass over the U.S. at the right time.
- NASA's Lunar Reconnaissance Orbiter studies the Moon and plans to point its camera at Earth to observe the Moon's shadow during the eclipse.

  https://eclipse2017.nasa.gov/observations

STUDYING THE MOON DURING THE ECLIPSE

Top left: Topography of the Moon, where cool colors represent low elevations and warm colors show areas with higher elevation.
Credit: NASA/GSFC/ LRO/LOLA

Bottom left: When sunlight peaks through the low points in the jagged lunar limb during a total solar eclipse, one can see phenomena known as Baily's Beads and the diamond ring effect.
Credit: Rick Fienberg/TravelQuest/ International/Wilderness Travel



https://lunar.gsfc.nasa.gov/images/LRO_Eclipse_Litho.pdf

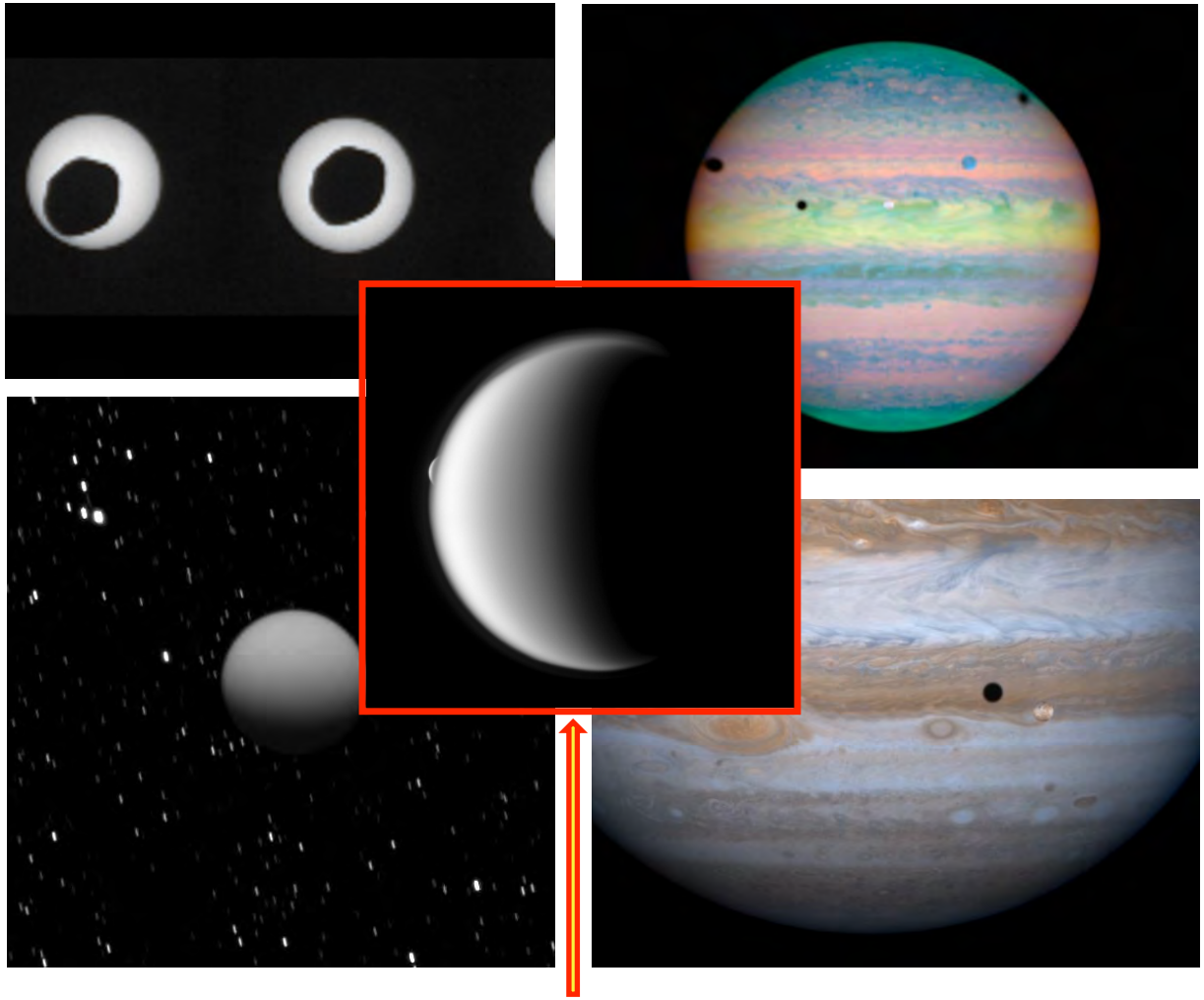
NASA's Lunar Reconnaissance Orbiter studies the Moon and plans to point its camera at Earth to observe the Moon's shadow during the eclipse.

Top right: The blue line surrounding the Moon shows the outline of the Moon's topographic profile, exaggerated 20 times.
Credit: NASA/SVS

Bottom right: Using LRO's topography data, one can predict precisely and accurately the location and duration of these phenomena, and the shape of the Moon's shadow on Earth.
Credit: NASA/GSFC/ASU

TRACKING PLANETARY ECLIPSES

NASA's Mars Curiosity rover viewed eclipse of the sun by Phobos on Aug. 20, 2013
Credit: NASA/JPL-Caltech/Malin Space Science Systems/Texas A&M Univ.



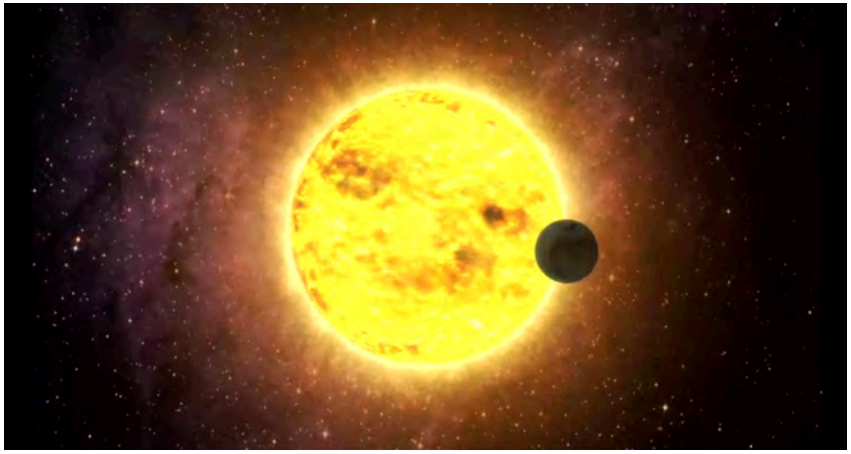
Hubble Space Telescope caught a rare triple eclipse (Io, Ganymede, Callisto) on the cloud tops of Jupiter on March 28, 2004.
Credit: NASA, ESA, and E. Karkoschka (University of Arizona)

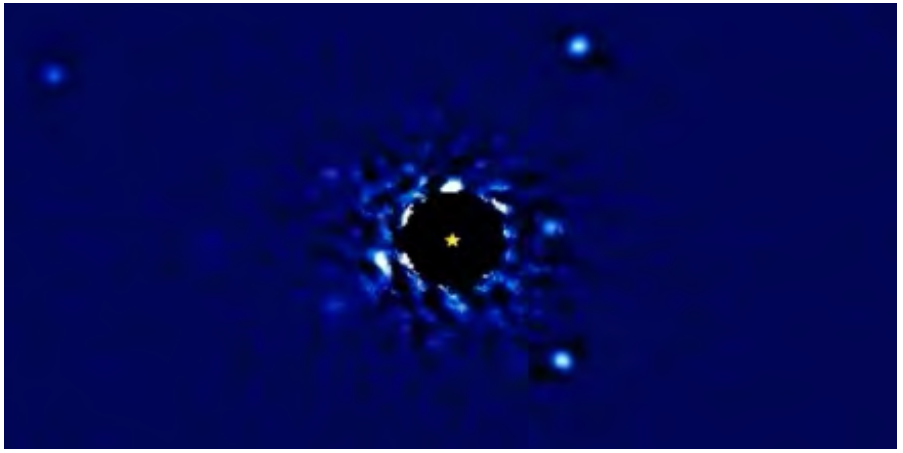
Cassini viewed Titan in eclipse by Saturn on May 7, 2009.
Credit: NASA/JPL/Space Science Institute

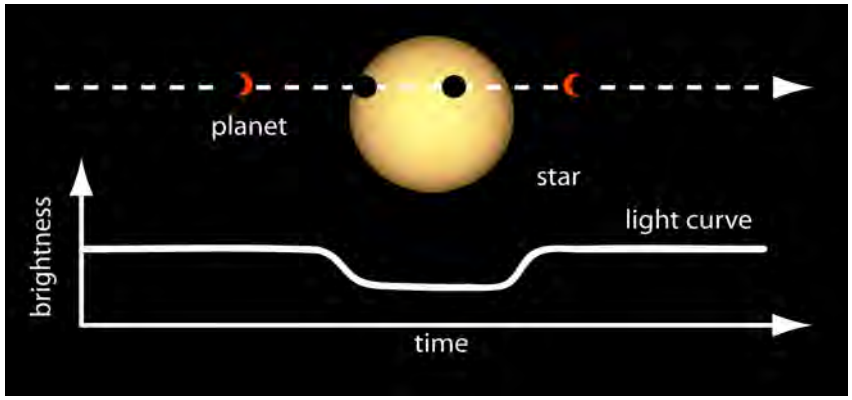
Cassini viewed Io eclipse on Jupiter's cloud tops in 2004.
Credit: Cassini Imaging Team, Cassini Project, NASA

Cassini watched Rhea emerge after being occulted by Titan on Oct. 27, 2009.
Credit: NASA/JPL/Space Science Institute

FINDING EXOPLANETS





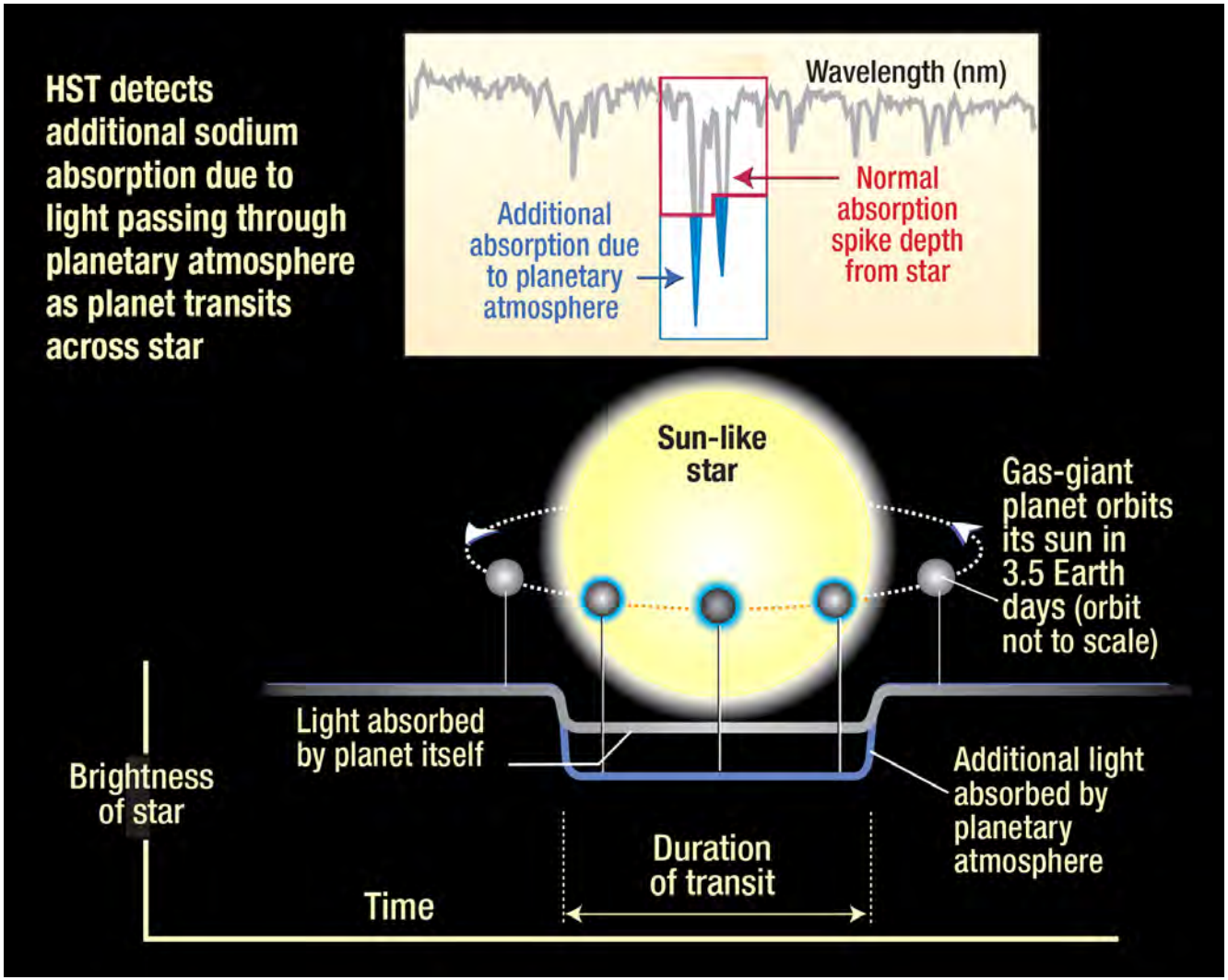


Top left: Transits of planets around distant stars are one way astronomers can detect these extra solar planets.
Credit: NASA GSFC

Bottom left: As the planet moves in front of the star, a small percentage of the light from that the star is blocked and the light curve dips. When the planet moves off the limb of the star, the light curve recovers. This method is only effective when the plane of the orbit of the planet is in our line of sight. Credit: NASA Ames

Top Right: See Four Planets Orbiting Star HR 8799.
Credit: J. Wang (UC Berkeley) & C. Marois (Herzberg Astrophysics), NExSS (NASA), Keck Obs.

FINDING EXOPLANETS (CONT.)



Credit: Space Telescope Science Institute/Ann Feild

In addition to transits of stars, planets can be detected by detecting gasses in their much cooler atmospheres. Here sodium is detected in the atmosphere of a planet from Hubble Space Telescope spectral observations. This observation of HD209458 (150 light year away) in the constellation of Pegasus was the first direct detection of a planetary atmosphere outside our solar system.

III. EDUCATION

Improving knowledge of the Solar System and our place in it.

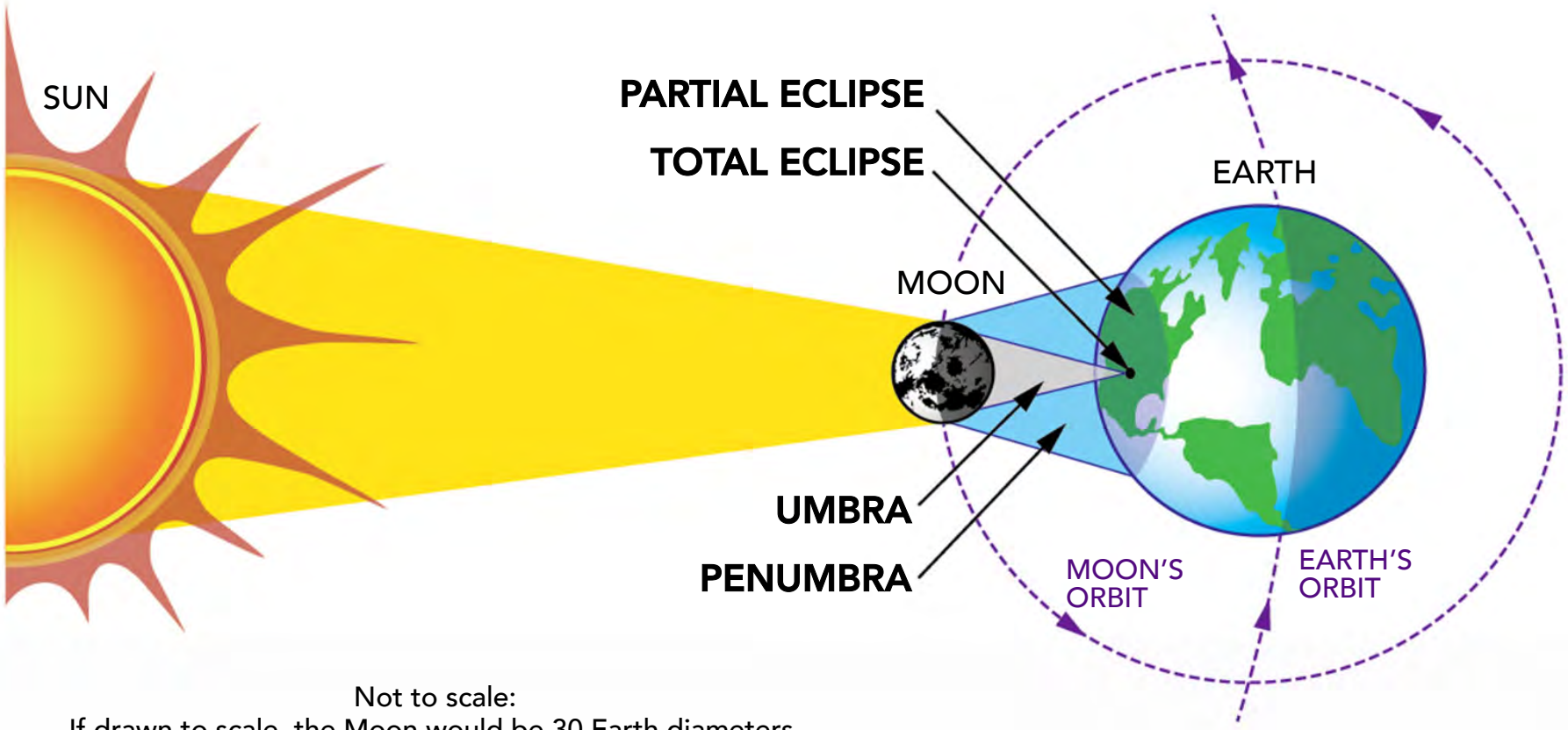
- In 2012, 24% of U.S. adults incorrectly answered the question: Does Earth revolve around the sun? (Hint, it does)

A fundamental learning opportunity of nature's processes:

- Orbital mechanics
- Why are eclipses so rare?
- When and where
- Eclipse phases
- What one may see during totality
- Historical drawing versus spacecraft observations

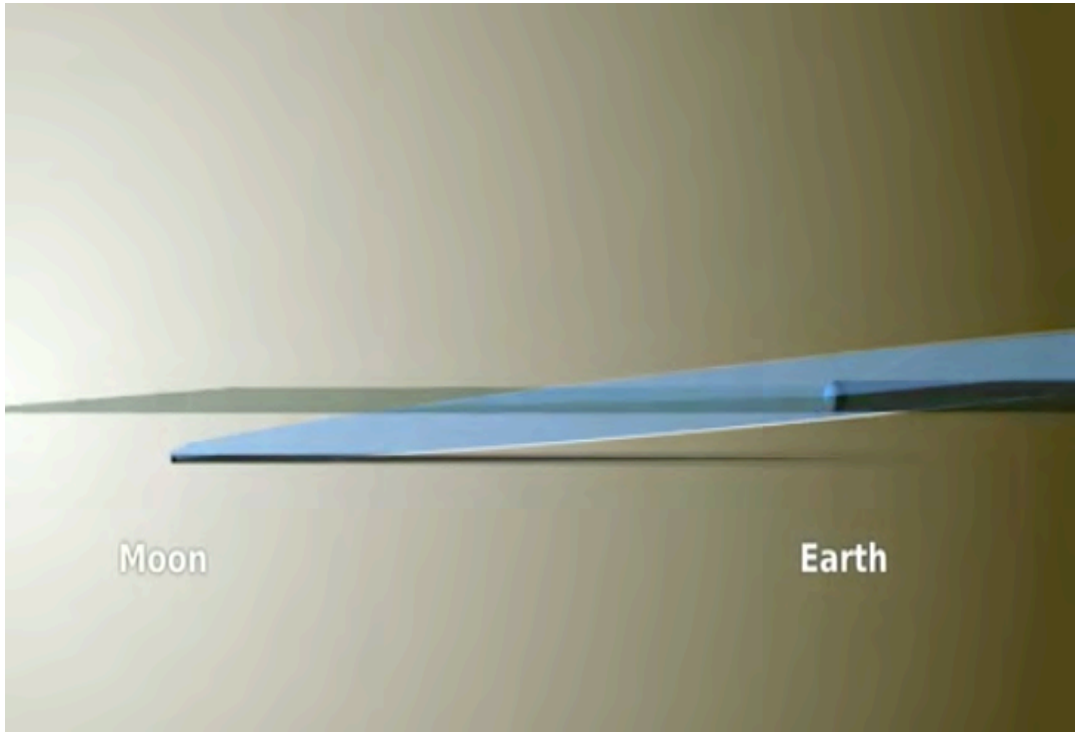
TOTAL SOLAR ECLIPSE: MONDAY • AUGUST 21, 2017

This will be the first total solar eclipse visible in the continental United States in 38 years.



Not to scale:
If drawn to scale, the Moon would be 30 Earth diameters away. The sun would be 400 times that distance.

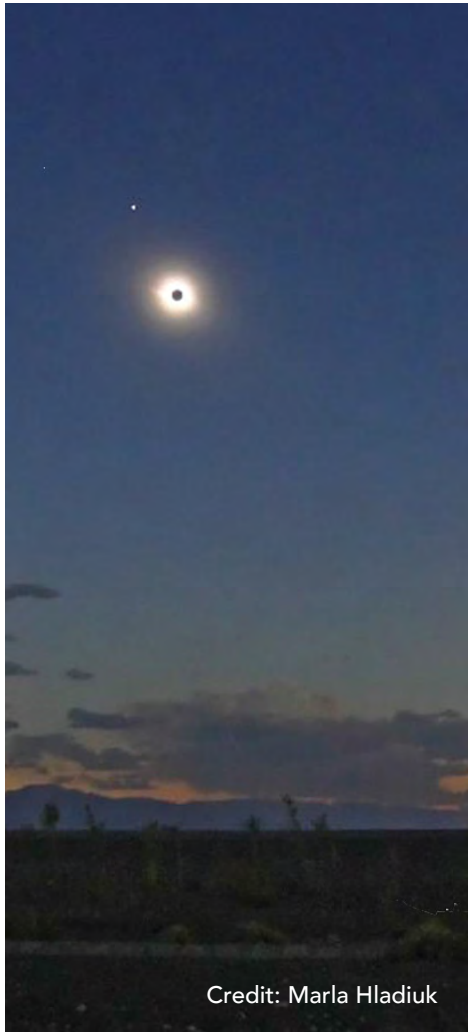
WHY ARE ECLIPSES SO RARE?



Download this animation at https://svs.gsfc.nasa.gov/4324

The Moon's orbit is tilted 5 degrees from the ecliptic, so it only crosses exactly between the sun and Earth about once every 18 months.

WHAT IS A SOLAR ECLIPSE?

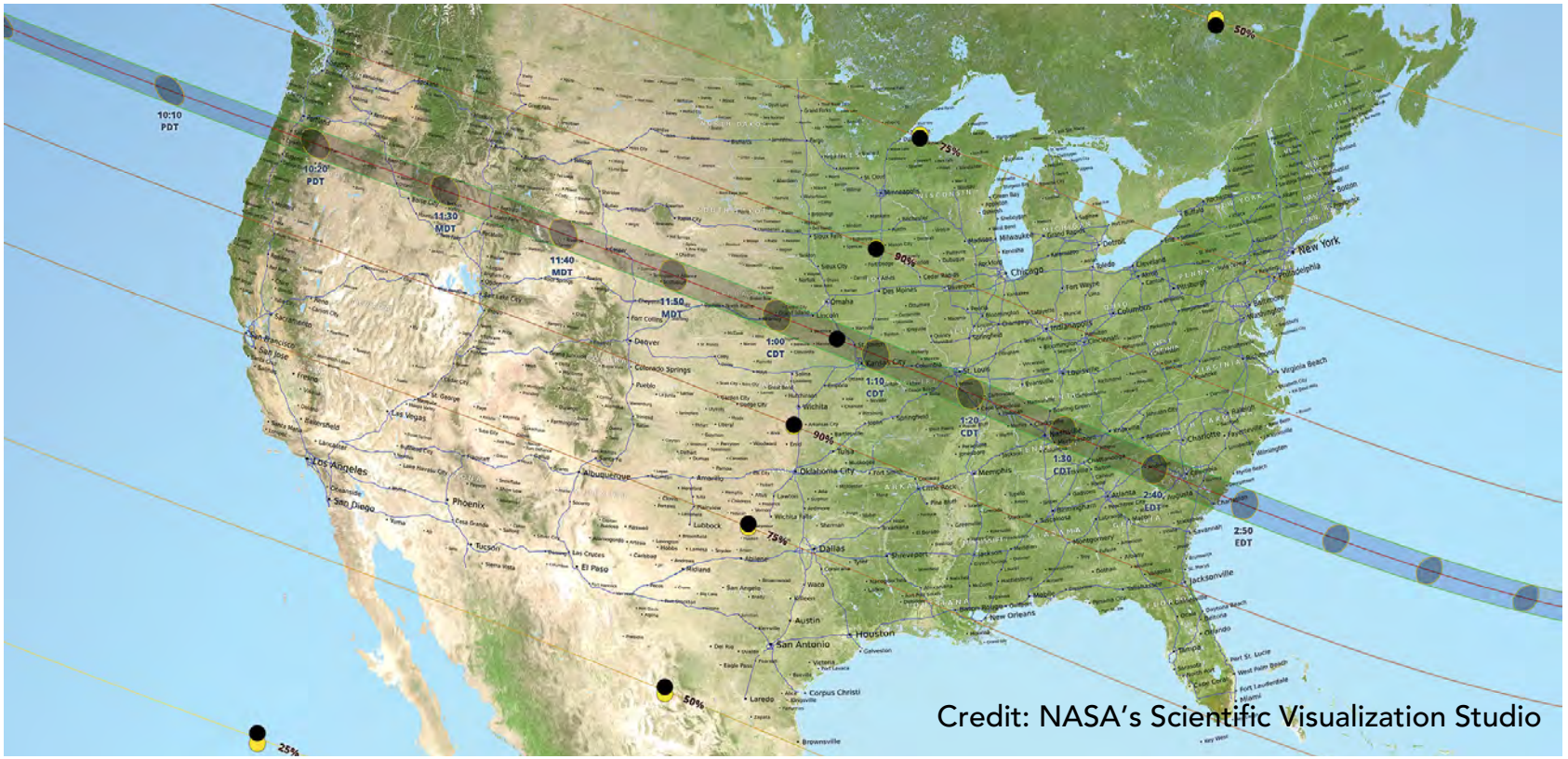

Credit: Marla Hladiuk

A solar eclipse happens when the Moon casts a shadow on Earth, fully or partially blocking the sun's light in some areas. Observers within the path of totality will be able to see the sun's corona (weather permitting), like the image on the left. Observers outside this path will see a partial eclipse.

THE NEXT ECLIPSE

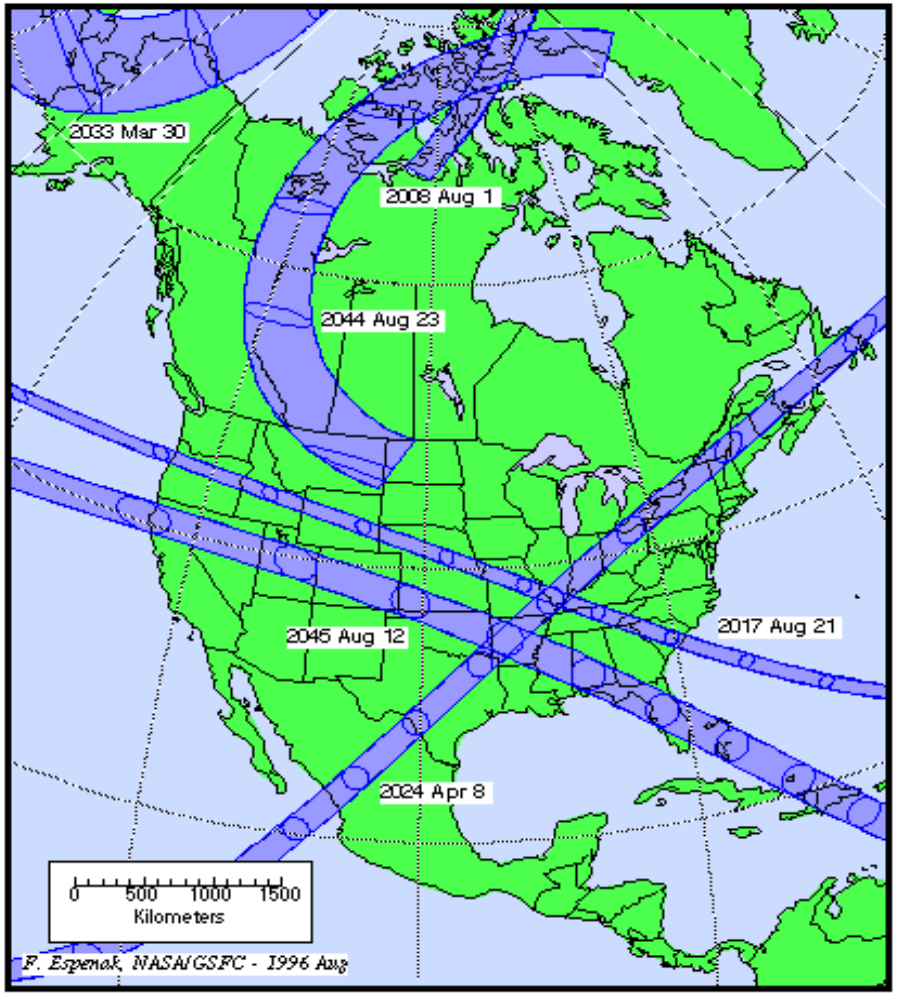
After the 2017 solar eclipse, the next total solar eclipse visible over the continental United States will be on **April 8, 2024**.

AUGUST 21, 2017: First total solar eclipse visible in the contiguous United States in 38 years

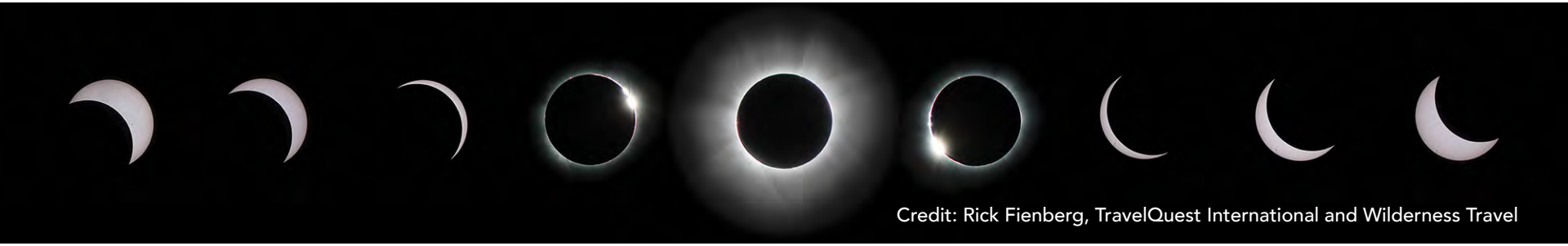


This map shows the path of the Moon's umbral shadow—in which the sun will be completely obscured by the Moon, called totality—during the total solar eclipse of Aug. 21, 2017. Outside the path of totality, the rest of the continental U.S. will be within the Moon's penumbral shadow, where the Moon only partially blocks the sun and creates a partial solar eclipse. The partial eclipse begins in the continental U.S. near Lincoln City, Oregon, at 9:05 a.m. PDT, and totality begins in this location at 10:16 a.m. PDT. The total eclipse will end in Charleston, South Carolina, at 2:48 p.m. EDT, and the partial eclipse ends in the continental U.S. in this location at 4:09 p.m. EDT. You can search online for eclipse times in your area or with this map, https://svs.gsfc.nasa.gov/4515

TOTAL SOLAR ECLIPSES ACROSS NORTH AMERICA 2001 - 2050

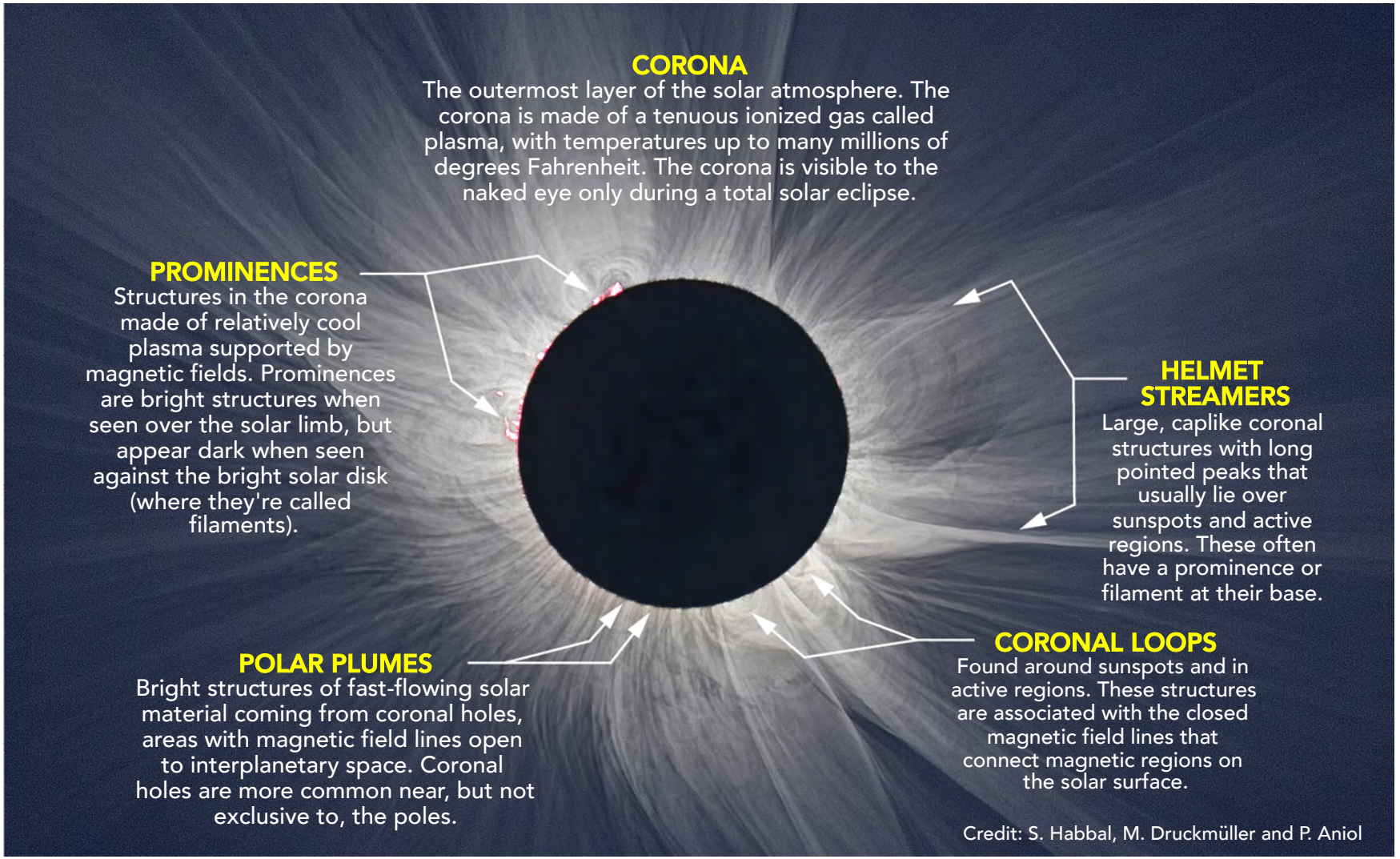


DIFFERENT PHASES OF A TOTAL SOLAR ECLIPSE

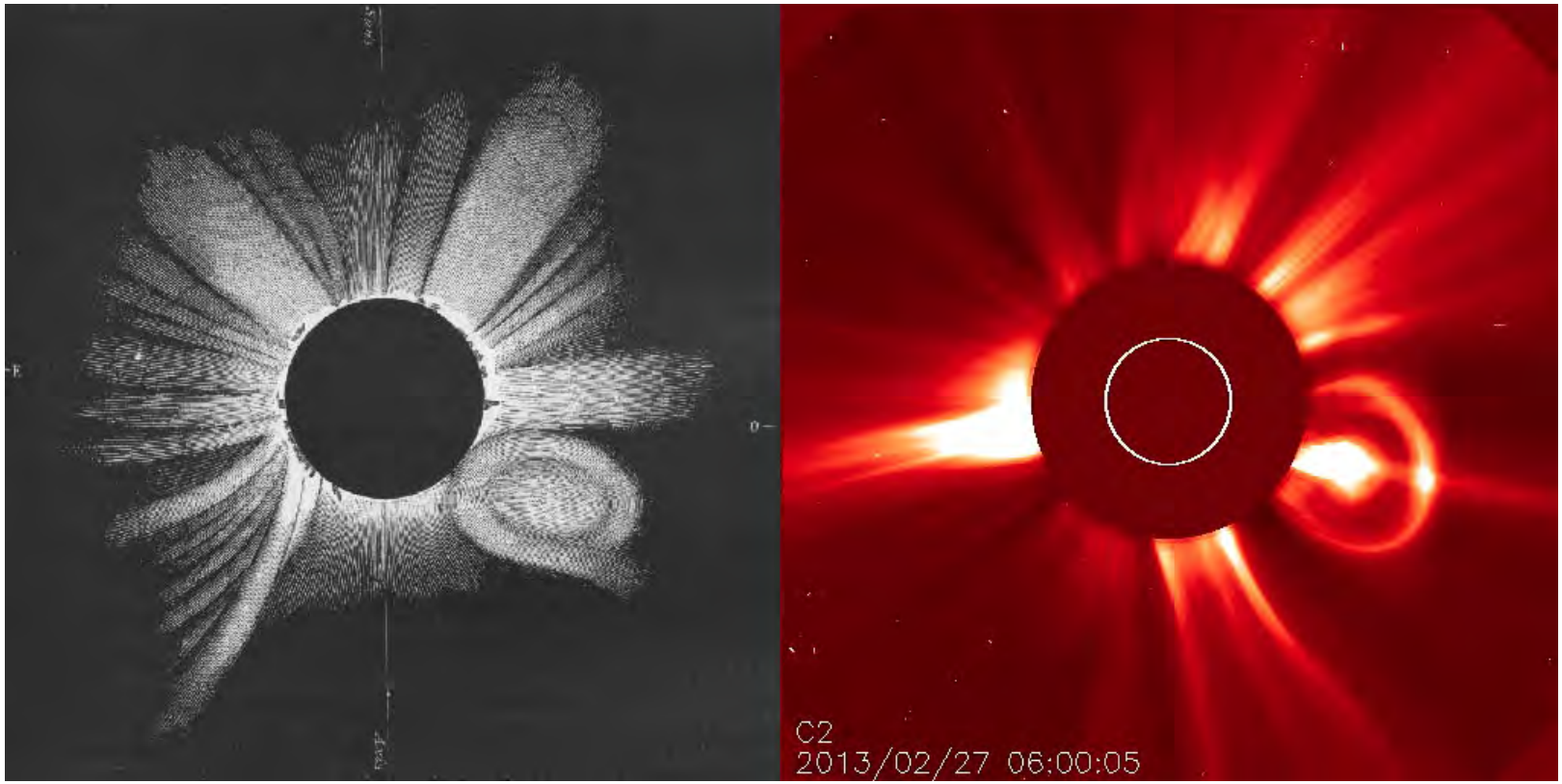


In this series of stills from 2013, the eclipse sequence runs from right to left. The center image shows totality; on either side are the 2nd contact (right) and 3rd contact (left) diamond rings that mark the beginning and end of totality respectively.

STRUCTURES IN THE SUN'S FAINT ATMOSPHERE VISIBLE DURING A TOTAL SOLAR ECLIPSE



CORONAL MASS EJECTIONS FIRST SPOTTED DURING A TOTAL SOLAR ECLIPSE (1860)



Left: Drawings of the 1860 eclipse by G. Tempel. Right: Modern-day instrument called a "coronagraph," which simulates a solar eclipse, blocking the sun to reveal the sun's outer atmosphere. Eruptions like the one depicted in Tempel's drawing are common observations in coronagraph images. Credit: ESA/NASA/SOHO

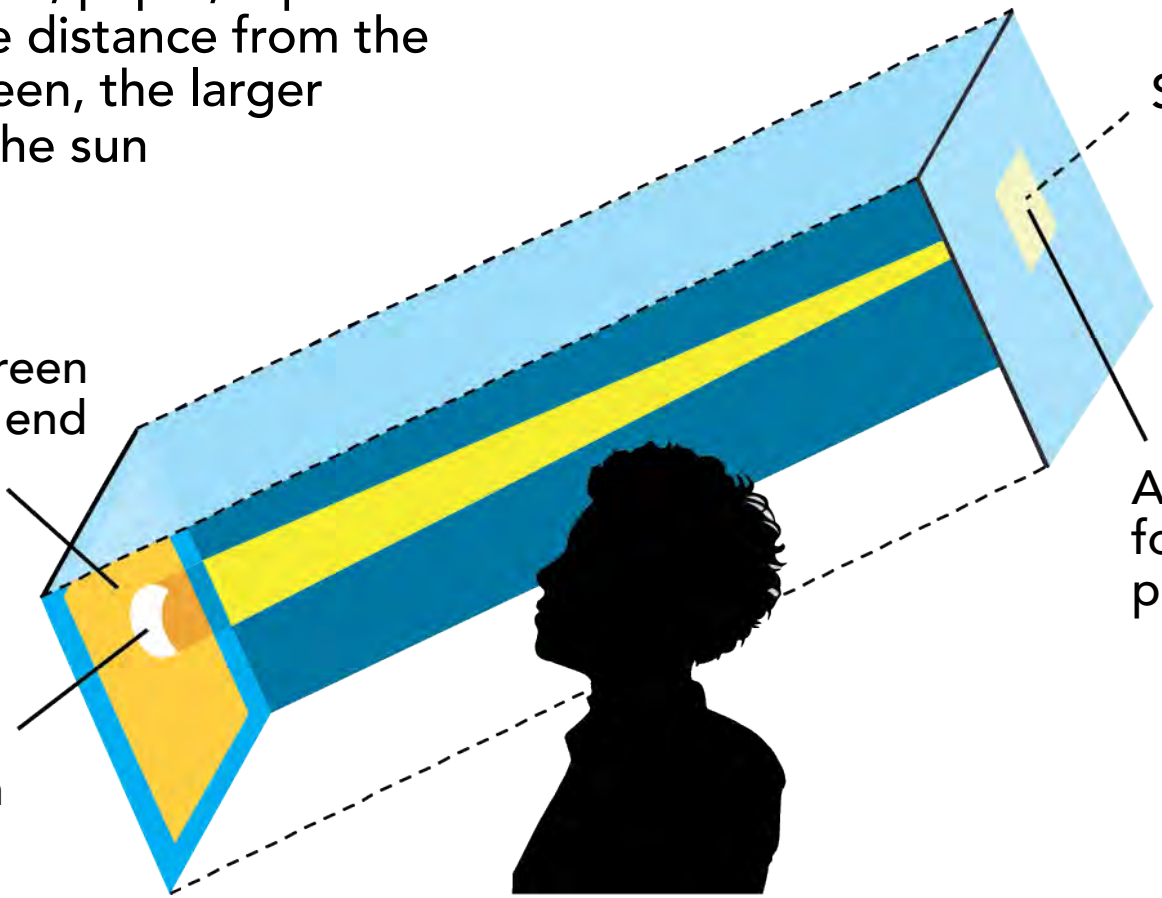
IV. PUBLIC ENGAGEMENT

Unique opportunity for all U.S. to participate:

- Make your own cardboard projector
- Mirror the solar eclipse image in an envelope
- Use 3-D printed pinhole cards as eclipse projectors
- Try citizen explorer activities
- Download more from the NASA eclipse website
- Additional resources for the eclipse and beyond
- Add your own eclipse event, *http://bit.ly/2lviRn9*

MAKE YOUR OWN CARDBOARD PROJECTOR

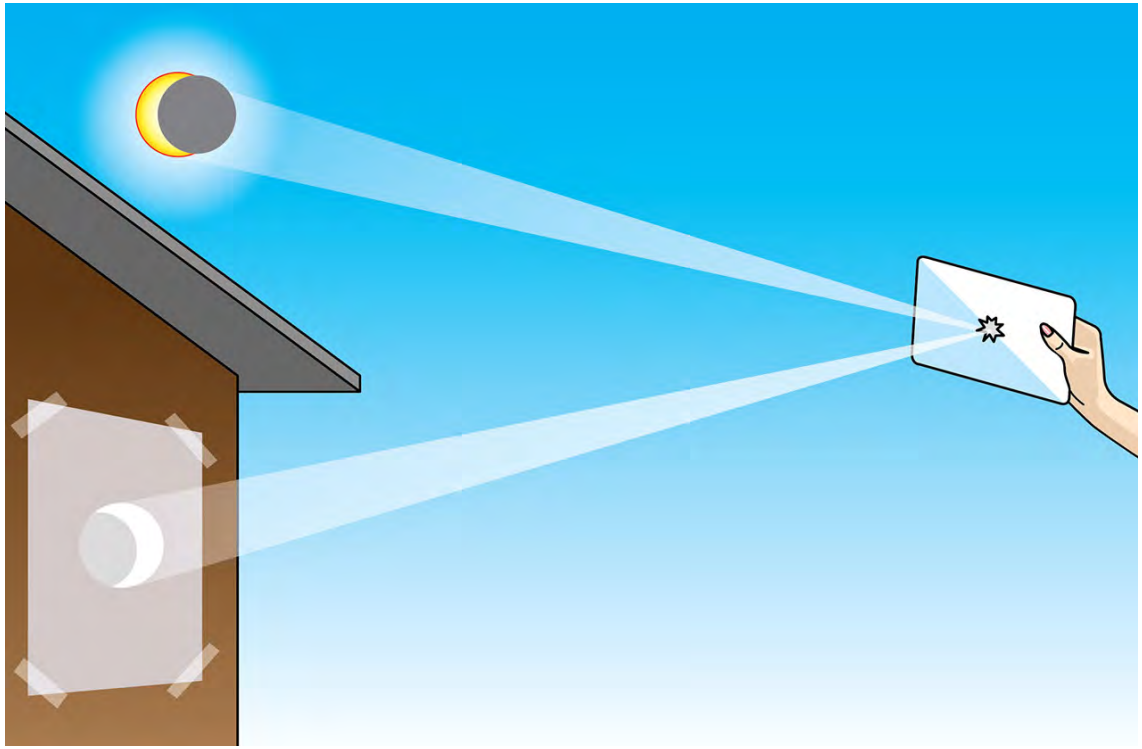
You can make this simple eclipse projector with some cardboard, paper, tape and foil. The longer the distance from the pinhole to screen, the larger the image of the sun will be.



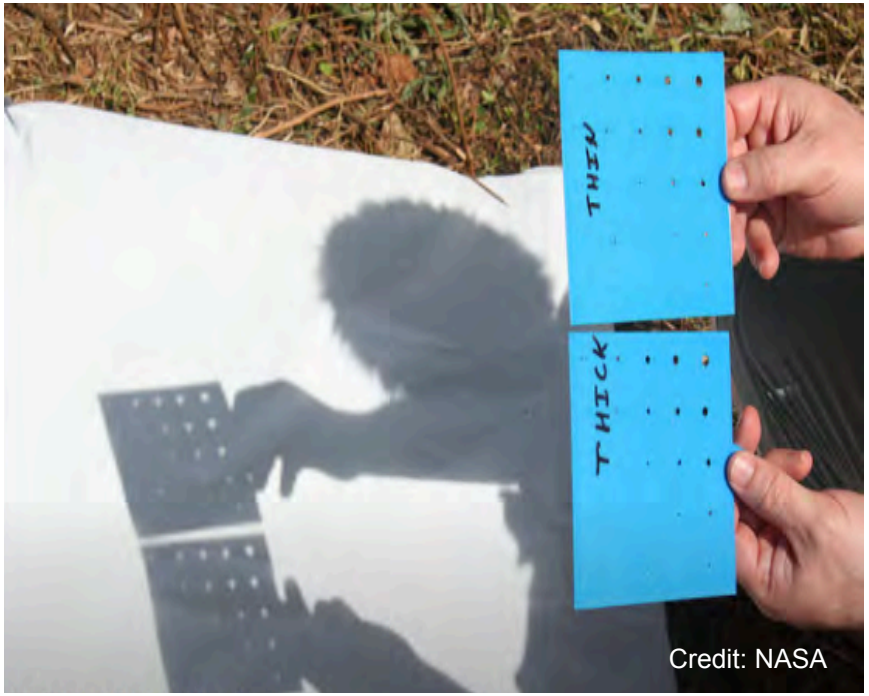
MIRROR IN AN ENVELOPE

Slide a mirror into an envelope with a ragged hole about 5/8 inch (1.5 cm) cut into the front. Point the mirror toward the sun so that an image is reflected onto a screen about 15 feet (5 meters) away. The longer the distance, the larger the image.

DO NOT LOOK AT THE MIRROR, ONLY AT THE SCREEN.



3-D PRINTED PINHOLE CARDS

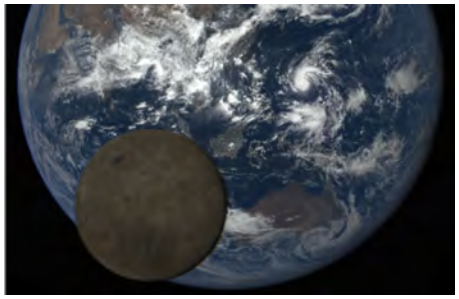


Design your own pinhole projector card or download one from *https://eclipse2017.nasa.gov/makers*

- STL files are available in the shape of all 50 states.
- Print one or more pinhole projection devices in advance, and decorate them.
- Place a pinhole near your viewing location or home town.
- Use your 3-D printed pinhole projector on August 21, 2017.
- Mark the occasion with a selfie of your shadow next to the shadow of your state and projected partial eclipse.
- Upload to flickr: *www.flickr.com/groups/nasa-eclipse2017*

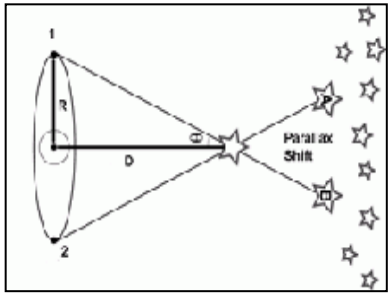
CITIZEN EXPLORERS

Mass of Earth



Credit: NASA/NOAA

Lunar Distance by Parallax



Credit: NASA

Diming of the Daylight

Credit: Olav Jon Nesvold/EPA

X Marks the Spot

Credit: NASA

Lunar Shadow Speed

Credit: MIR Cosmonauts

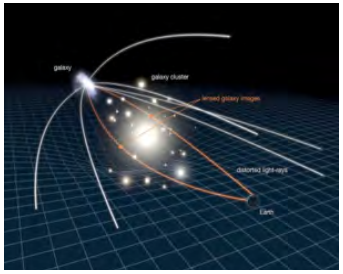
Measuring Temperature

Credit: NASA/GLOBE

Lunar Distance from Speed

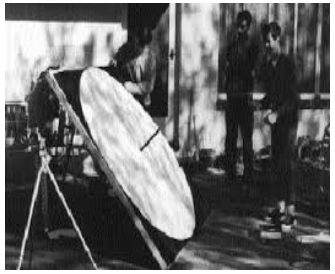
Credit: Fred Espenak

Testing General Relativity



Credit: NASA/ESA

Shadow Bands



Credit: Karl Simmons, Mike Reynolds

https://eclipse2017.nasa.gov/citizen-explorers

NASA ECLIPSE RESOURCES

Do you need ideas to engage your audiences? Try the following:

- **Activities**: try some for outdoor and indoor:
  - *https://eclipse2017.nasa.gov/activities*
- **NASA's Eyes on the 2017 Eclipse**: see a 3D simulation
  - *http://eyes.jpl.nasa.gov/eyes-on-eclipse.html*
- **Toolkit**: watch videos, download banners, fact sheet, safety bulletin, star chart/bookmark, and tips to organize eclipse parties
  - *https://eclipse2017.nasa.gov/toolkit*
- **Event Maps**: find museums, libraries, parks and other organized eclipse events closest to you
  - *https://eclipse2017.nasa.gov/eclipse-maps*

NASA RESOURCES FOR ECLIPSE AND BEYOND

- **Apply to become a Solar System Ambassador or invite one to your event:**
  - *http://solarsystem.nasa.gov/ssa/home.cfm*
- **NASA's Eyes on the Solar System**: learn about your home planet, our solar system, the universe beyond and the spacecraft exploring them
  - *https://eyes.nasa.gov/*
- **NASA's Night Sky Network**: join a nationwide coalition of amateur astronomy clubs
  - *https://nightsky.jpl.nasa.gov/*
- **Astronomical League**: find astronomy clubs near you and joint NASA observing challenges
  - *https://www.astroleague.org/*
- **Celebrate International Observe the Moon Night:**
  - *http://observetheMoonnight.org/*
- **Learn more about NASA's science research and missions:**
  - *https://science.nasa.gov*
- **Find NASA visualizations, animations, and images by key words and topics:**
  - *https://svs.gsfc.nasa.gov/Gallery/suneclipse2017.html*

V. CITIZEN SCIENCE

Several apps to gather data on nature's processes:

- iNaturalist App
- GLOBE Observer App
- Google Science Journal
- Other free apps!!

GATHER DATA ON NATURE'S CHANGES

- iNaturalist App: Observe and record plant and animal behavior changes

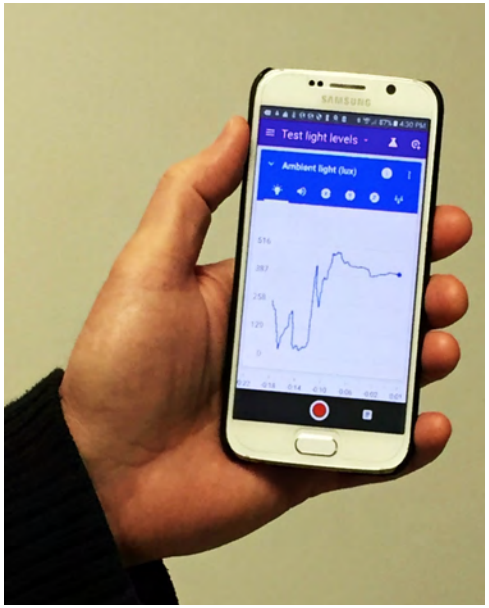
Credit: The GLOBE Program

- GLOBE Observer App: Join the GLOBE community and contribute scientific data to NASA and GLOBE, your local community, and students and scientists worldwide
- Download this free app from the appropriate iOS and Android stores.

GOOGLE SCIENCE JOURNAL

Credit: Science Journal app store

Credit: NASA KSC



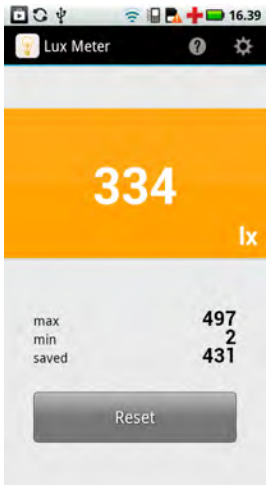
Credit: NASA

- Collect data in the palm of your hand
- Use phone sensors as accelerometer, magnetometer, light and sound sensors
- Open source code
- Can attach external sensors
- Eclipse applications include light level and sound
- Find this free app from the appropriate Android store

SOME INTERESTING APPS

Screenshot of temperature on a smart phone

- OmniTemp – Use this free app with its inexpensive, external temperature probe to measure temperature changes during the eclipse.



Screenshot of luminosity on a smart phone

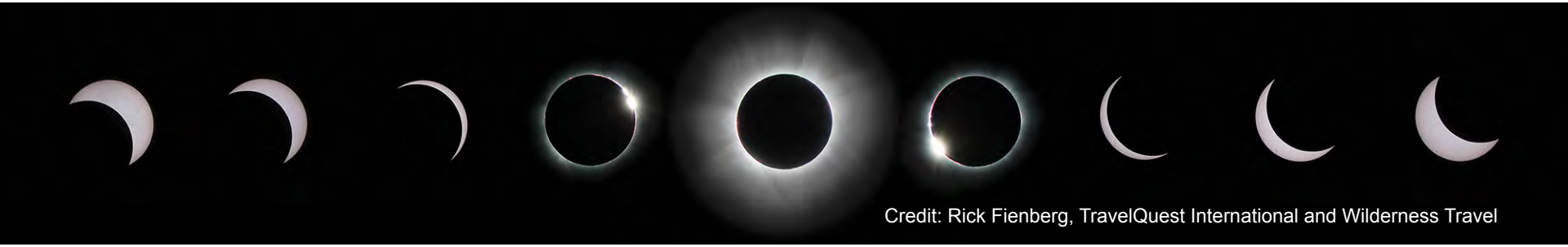
- LuxMeter – Use this free app to measure daylight brightness changes during the eclipse.

Find these free apps from the appropriate app stores.

VI. ON THE DAY OF THE ECLIPSE

- Safety first!!
- Watch
- Enjoy

ON AUGUST 21, 2017



Whether or not you are in the path of totality:

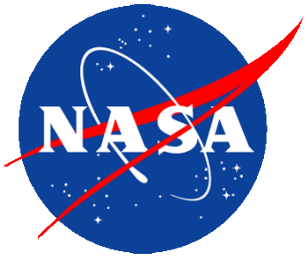
- Practice safe eclipse observations
- Find a free "Total Solar Eclipse" app from Android or iOS app stores to watch live video streams
- Watch NASA live broadcasts from multiple locations:
  - *http://www.nasa.gov/TV*
  - *http://eclipse2017.nasa.gov*
  - *http://www.nasa.gov/eclipse*
- Enjoy a great eclipse party with your audiences!

IMPORTANT INFORMATION

- You and the event coordinator should be aware that being a Subject Matter Expert (SME) for an event does not mean that you are a NASA representative. Any opinions you share as a SME are not necessarily the opinions of NASA.

- All negotiations involving compensation, travel, lodging, dates, etc. will be between the event coordinator and you. We are acting solely as the catalyst and handshake between events and subject matter experts. Please stay in contact with, and direct all questions about the event to your event coordinator.

- We appreciate your providing proper captions and credits when using maps, infographics, images or videos that were created by NASA and otherwise.



Thank you for volunteering as a subject matter expert!

More on eclipses	http://eclipse2017.nasa.gov http://www.nasa.gov/eclipse
More on safe viewing of eclipses	http://eclipse2017.nasa.gov/safety http://go.nasa.gov/2evRZBG

We welcome questions and comments at
https://eclipse2017.nasa.gov/contact-us